§18. Kinetic Ballooning Mode in s-α Tokamak

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A simple concentric tokamak are described by the model MHD equilibrium with two parameters; shear s and pressure-gradient α, which is known to s-α model. Thus the linear ideal ballooning modes are characterized by these two parameters. When we consider more exact formulation than the ideal MHD, such as gyrokinetics or two-fluid model, the only one parameter α in the s-α model is decomposed into $\alpha=-q^2Rd\beta/dr=q^2[(\beta_e+\beta_i)R/L_n+\beta_eR/L_{Te}+\beta_iR/L_{Ti}]$, which includes betas, density gradient and temperature gradient for each species. Here $1/L_X$=-dlnX/dr.

In this report, the linear stability in a s-α tokamak is investigated based on the gyrokinetics. The modes are electromagnetic shear Alfven modes, so called KBM. We concentrate on α parameter dependence, and the results are compared with ideal ballooning case. $\beta_i=\beta_e=\beta/2$ is assumed, and β, R/L_n, R/L_{Ti}, and R/L_{Te} are scaned for α. Other parameters are fixed: s=0.78, q=1.4, r/R=0.18, $k_\theta\rho_{thi}$=0.4.

The results are shown in Fig.1. From top to bottom, the gradient $1/L_n$, $1/L_{Te}$, and $1/L_{Ti}$ respectively are changed separately for α, and other gradients are set to zero. Followings are expected as main kinetic effects: (i) ion FLR effects, (ii) trapped particle effects, and (iii) $k_{//}v_{//}$ resonance.

For $1/L_n$- and $1/L_{Te}$-KBM, the 1st stability boundary almost coincides with that of ideal MHD. On the other hand, $1/L_{Ti}$-KBM is unstable lower than the MHD 1st stability boundary. This may be a result of coupling of ITG branch and KBM branch, with $k_{//}v_{//}$ resonance. There is a possibility that the $1/L_n$-KBM can also be coupled with the TEM driven by $1/L_n$ to make the 1st stability boundary lowered; however it is not found. This may be because the sign of real frequency of TEM is positive and opposite to that of KBM (coupling needs the jump). As the gradient increases, the FLR effects become strong for $1/L_n$ and $1/L_{Ti}$ cases. Simple FLR model suggests that the stabilization of FLR by $1/L_{Ti}$ is as twice strong as that for $1/L_n$. Thus, $1/L_{Ti}$-KBM is stabilized at sufficiently lower critical α than that of MHD. For $1/L_n$- and $1/L_{Te}$-KBM, the trapped particle (TP) effects can also be effective. Unlike the conventional analytic arguments, the TP effects are found to be destabilizing. In the $1/L_n$ case, the stabilizing FLR and destabilizing TP effects co-exist, and the 2nd stability boundary is almost the same as that of MHD. On the other hand, since FLR never work for $1/L_{Te}$-KBM, it is unstable well beyond the MHD boundary, by the TP effects. In usual experiments, these different gradients co-exist, and both the 1st and 2nd stability boundary will not coincide with that of ideal MHD.

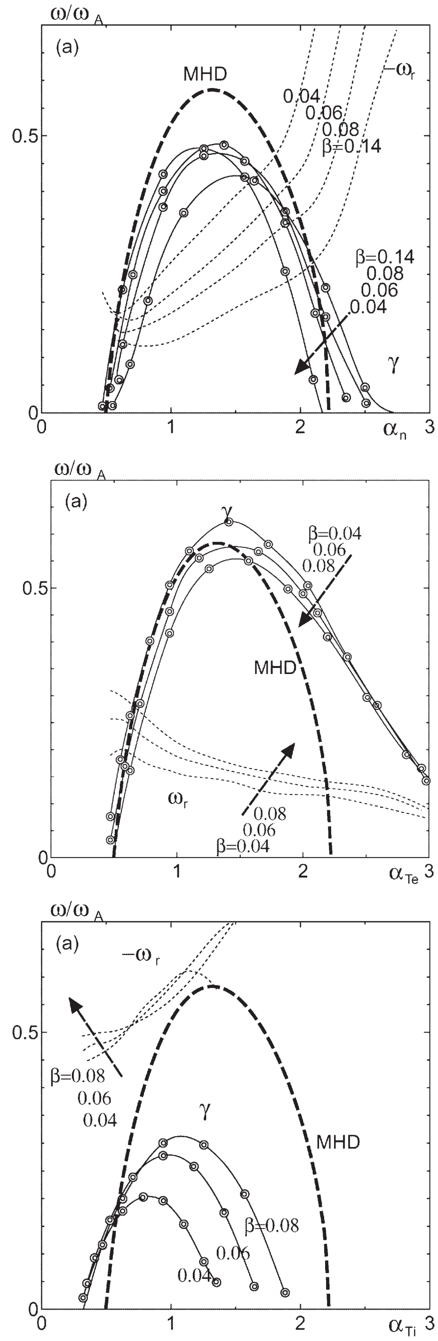

Figure 1: KBM growth rate(lines with marks) and real frequencies(dotted lines), and ideal MHD growth rate (thick dashed lines), which are driven by the density gradient(top), electron temperature gradient(mid), and ion temperature gradient(bottom).